A NEW METHOD FOR UNCONSTRAINED HEART RATE MONITORING

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***Abstract*- A new method to measure heart rate, respiration and body movements without attaching measuring device to the subjects is proposed. It is a kind of ballistocardiograph that uses optical fiber and measure changes of transmitted light intensity in optical fiber induced by stress-optical effect caused by ballistocardiogram.**
***Keywords*- patient monitoring, heart rate, unconstrained, ballistocardiogram, stress-optical effect, optical fiber**

I. INTRODUCTION

A study conducted by the Ministry of Health and Welfare of Japan revealed that 26 percent of Japanese spend more than one year, and 13 percent three years, bedridden before they die. They need to be cared and now many of them are cared at their home by their family members. However, care of bedridden elderly persons are not easy task, and this caused severe psychological and financial problems for other family members. These problems sometimes cause hospitalizations before the older person really needs medical care, and result a national lack of nursing man power and skyrocketing medical costs in recent Japan.

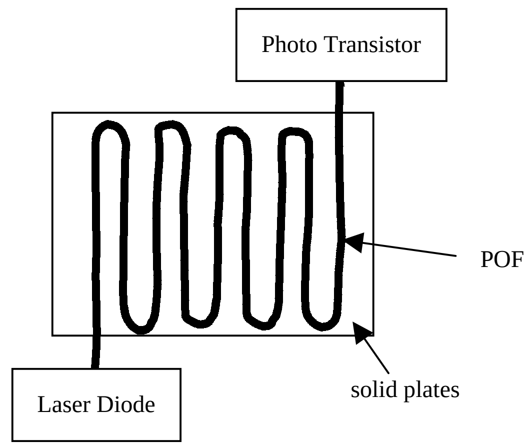
Our motivation in this study is to develop a convenient remote monitoring tool of physical and mental conditions of bedridden elderly people at home and patients at hospitals and to contribute to the labor saving of the care and the nursing. Here, we propose a new method to measure heart rate, respiration and body movements without attaching measuring device to the subjects. In this report we introduce measuring principle and preliminary results of this new method.

II.MEASUREMNT

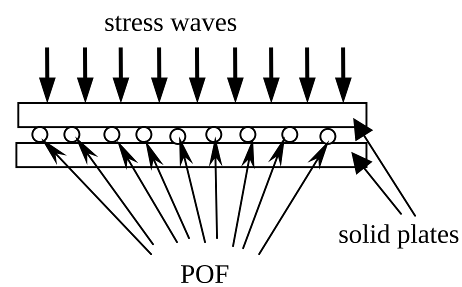
The principle of our method is to measure the change of optical properties of transparent solid material due to stress-optical effect caused by ballistocardiogram (BCG)[1][2], respiration and body movements of subject sitting or lying on that material. To extract slight stress waves due to BCG et al. from superimposing subjects weight, we have to localize stresses and have to use materials with large stress-optical coefficients. For this purpose, we employed plastic optical fibers (POF).

Measuring device used in this study is schematically shown in Fig.1. POF (Esca, Mitsubishi Rayon, made by PMMA (Poly (methyl Methacrylate)), diameter 0.25mm, length 10m) were sandwiched by two solid plates (PMMA, A4 paper size, thickness 5mm) which uniform stress distributions. Using a laser diode (Sanyo DL-3149-056, 670nm, 5mW) and photo-transistor (Toshiba, TPS601) we measured changes of light intensity transmitting through the POF.

With this device, we performed the measurement of pulse numbers. We set this device on a chair and let subjects sit on it and keep stable. We measured light intensity changes for 20 seconds. For the sake of comparison, we measured finger photo-plethysmograms (FPPG) at right forefinger of subject simultaneously.



a) top view



b) side view

Fig.1 Measuring device

III.RESULTS AND DISCUSSION

Typical results of transmitted light intensity (TLI), FPPG and their cross correlation are shown in Fig.2. By visual inspection of TLI, it is obvious that TLI has same periodicity component with FPPG. Their cross correlation further supports that pulse number can be obtained by TLI data. Power spectrums of TLI and FPPG are shown in Fig.3. Both spectrum show peak at 1.24Hz, thus we can obtain average pulse number of this 20 second duration is 73.4.

Although we used high-pass (cutoff frequency (fc), 0.5Hz) and low-pass (fc, 2.0Hz) filters in the amplifier of TLI signal, their rather broad transition bands (12dB/oct) made power spectrum of LTI very broad. The use of sharp band pass filter simplifies LTI spectrums and we can obtain pulse numbers without using supplemental measurement such as FPPG. As a post-processing, this is easily achieved, however,

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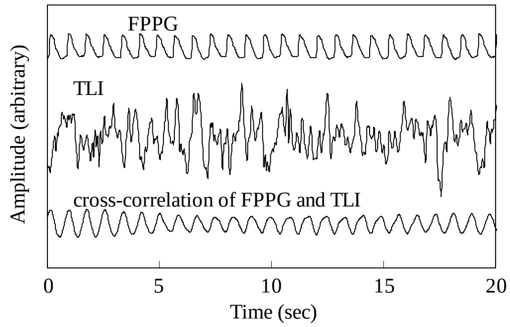

Fig.2 Typical example of transmitted light intensity (TLI), finger photoplethysmogrm (FPPG) and their cross-correlation.

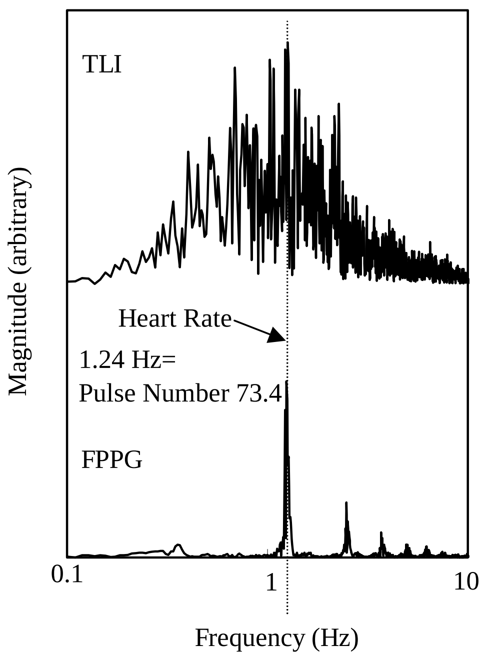

Fig.3 Power spectrums of TLI and FPPG.

for our purpose, on line filtering is necessary.

It is well known that BCG signals have multiple peaks during one R-R interval of the heart [1][2]. This is one reason that the power spectrum is complicated. If we can eliminate harmonics higher than the second and extract only fundamental wave by analogue circuit, this will be the most efficient way of on-line band pass filtering. Furthermore, since the fluctuation of periods of fundamental wave is equivalent to the fluctuation of R-R intervals, we can monitor the activity of the autonomic nervous system of subjects. Now, we are designing this fundamental wave extracting circuit.

Here let us overview the history of BCG and discuss the advantages and disadvantages of our method. In 1936, Starr recognized that the BCG closely reflects myocardial contraction.[1][2] In spite of the great potential value of the BCG in that it directly reflects heart action, the BCG has never come into clinical use.

Early BCG equipments were beds that can move horizontally and adjusted very sensitive to body movements transferred from the subjects sleeping on them. Recording BCG were recording displacements of these beds caused by ventricular contraction or blood flow bending at the aorta arch etc. of subject. Thus, measuring BCG requires that the patient should move from his own bed to these special beds for cardiological examination, and BCG was not a method for daily monitoring or long term monitoring of patients.

As a BCG method for patient monitoring, Alihanka et al.[2] proposed a static charge sensitive bed which is essentially a wide area capacitor set under a normal foam plastic mattress of patient's beds. It measures potential differences induced between two electrodes due to static charge distribution caused by various body movements of patient lying on a mattress. Now their system is commercially available (Bio-Matt, Biorec, Finland) and widely used for sleep studies. Although Bio-Matt may be the most convenient BCG equipment at present, it is very large and has complicated structure. Hence it is not suitable for home care of bedridden elderly people.

Our method provides very small, simple and mechanically rugged device suitable for home use by non-experts. However, there remains some barriers we have to overcome. They are; 1) lowering the sensitivity during long time monitoring, and 2) the existence of dead time after measurements. These are originated by the deformation behaviors of polymeric materials[3]. At first deformation of valence angles and bond length take place when polymeric materials is stressed. Then molecular re-orientation gradually proceeds during long time stressing and lowers the sensitivity. When stress is removed, polymeric materials gradually recovers to the initial orientation. During this recovery process, POF yields the change of LTI without subjects. For us, this period acts as the dead time. To avoid molecular re-orientation, we can 1) lengthen the POF used in device and decrease stress level per unit length of POF, and 2) use POF with polymeric material whose chemical structure strongly restricts molecular re-orientation[3].

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